Human Systems and Aircraft Maintenance

Nick MCDONALD

Research in normal operational environments indicates that the formal requirements for the aircraft maintenance system are frequently not fully or effectively implemented in practice. This gives rise to a pervasive 'double standard' with no effective means of reconciling official and unofficial operational practice. A systems strategy for human-centred management in aircraft maintenance is being developed in a number of European projects, which address issues of design, planning, operational practice, monitoring, change and competence.

The primary elements governing the European aircraft maintenance system include the Joint Aviation Requirements (JAR) and the Air Transport Association's (ATA) specifications for maintenance documentation.

JAR 145

The framework of JAR 145 regulations is built around the philosophy of granting approval to maintenance organisations which have an adequate management system to ensure safe operations. Thus the regulator only indirectly regulates the safety of the operation - the responsibility is on operational and quality management to ensure safety. In particular this devolution of responsibility for safety and airworthiness is expressed through the requirements to designate an accountable manager and to have an independent quality system which includes a feedback system to ensure corrective action.

The manufacturer

The principle specification relevant to maintenance documentation is ATA specification 100 which sets out guidelines for the manufacturer for producing maintenance documentation, such that "the Aircraft Maintenance Manual (AMM) shall provide the necessary procedures to enable a mechanic who is unfamiliar with the aircraft to maintain the aircraft properly." Manufacturers are also particularly concerned to ensure that documentation is comprehensive accurate and up to date.

The maintenance organisation

The Maintenance Exposition Document is compiled in compliance with the regulations of the European Joint Aviation Authorities governing maintenance organisations (JAR 145). The document contains the company's formal information on Maintenance Management (i.e. roles, responsibilities, accountabilities), Maintenance Procedures (Line, Light and Base), and Quality Systems Procedures.

The maintenance technician

The maintenance technician operates under a set of approvals to undertake maintenance work on specified aircraft types, and to certify that the work has been carried out according to the correct procedures. The basis of this is the certification of competence in compliance with the requirements of JAR 66.

How does the organisational system work in practice?

The ADAMS project provided the opportunity to study the functioning of four European aircraft maintenance organisations. Unless otherwise stated the research discussed below is reported in McDonald et al. [1]

Quality and safety

Auditing practices vary widely between different maintenance organisations and national aviation authorities. While all organisations place emphasis on effective auditing of documentation, some audit fixed facilities and resources, but few attempt to audit how work is actually done. There are no common auditing standards.

Few quality-reporting systems work as they should, particularly in dealing with human factors information. Some organisations are only starting to implement a quality discrepancy reporting system, and either it only covers part of their operation or many technicians are not aware of its existence. For some it is not seen to be sufficiently independent of the disciplinary process to be fully trusted. For others there is a large volume of reports which give rise to a backlog and long delays on responding. Part of the problem is reported to be getting managers to take responsibility for dealing with reports when they have other more pressing matters to attend to [2].

Organisations are not learning from their incidents. Following incidents or accidents, it is critical to future safety that organisations learn from what has happened and implement change to prevent similar incidents occurring. This is particularly true of the human and organisational factors which contribute to incidents. It is hard to find information on cases where learning and change has occurred. The Case Study on "Organisational learning from incidents" [2] demonstrates that, often, despite focused efforts to solve the problem, incidents may have to occur several times before effective change happens. Organisations are rarely systematic in their follow-up to non-technical aspects of incidents, specifically the implementation of recommendations, the monitoring of their effectiveness in addressing the problems they are designed to change and ensuring that knock-on problems are avoided.

Planning and organisation

For many companies, the traditional functional organisation with an established hierarchical structure and areas of specialisation dictates a top-down process of planning and organisation. For example, the Engineering department oversees the higher order and long term planning and produces the maintenance schedule (MS) for each aircraft. The Planning department receives the MS from the Engineering department and produces, certifies and dispatches work-packs required to accomplish scheduled maintenance. The scheduling section in the Production area then receives the work-packs from the Planning Department and further breaks the packs down into the daily work. On completion of the checks on the aircraft the Planning department then audit and maintain the work-packs and any other records for the aircraft. This top-down system tends not to be flexibly responsive to the needs and problems of the production system because strong organisational boundaries and little opportunity for feedback prevent the effective co-ordination of work.

Some organisations are trying to move to a more process-based organisation that in effect calls for the break-down of traditional departmental barriers in which the overall planning process is cross-functional. Thus, while engineering, planning and material departments still exist, the planning process involves the integration of these to oversee the planning of long term and day to day maintenance activities. The planning and co-ordination of daily work take place within production control centres located in the hangars. The make up of the production control centres brings together functions previously carried out in planning, materials and engineering.

Quality of documentation

In most of the organisations studied, the quality of the documentation available to the maintenance technician (especially through microfilm readers and printers) fell well below basic ergonomic standards. Even where modern CD ROM systems were available they were not often used. Training was rarely provided in their use. On the other hand every technician will admit to using 'black books' - unofficial documentation. This documentation is not available to scrutiny or inspection because of its illegal status.

Compliance with procedures

Maintenance engineers completed 286 questionnaires after they had completed a task. The questionnaire sought primarily to discover the normative level of deviation from task procedures, as well as inquiring into the reasons behind this non-conformance. 34% of respondents reported not-following the official procedure for the task. The most common reason given was that there was an easier way than the official method (45%) followed by 43% saying there was a quicker way. A number of factors which were related to increased likelihood of non-conformance were identified. Those individuals who consulted the manual but did not follow the official method were significantly more likely to report that:

- the task card was unclear;
- the necessary steps to complete the task were unclear;
- to have employed guesswork or trial and error;
- to report that the maintenance history was desirable but unavailable.

Major incidents

Increasingly, evidence from major incident and accident enquiries ([3], [4], [5]) is implicating failures at an organisational and regulatory level. Of particular concern are situations where there have been a series of incidents exhibiting similar underlying organisational problems, while the immediate characteristics of the incident might be quite different. For the official investigators and the authorities, it is difficult to know whether the recommendations from investigations have been implemented and, if so, whether they have been effective [6].

Implications of the evidence

What inferences about the normative system of aircraft maintenance can be made from these disparate observations about how it is practised? Several generalisations stand out:

- for many organisations the top-down nature of their planning systems means that they tend to be relatively unresponsive to the short-term requirements of production. There is little opportunity for feedback and organisational boundaries inhibit effective coordination;
- while virtually everyone admits using unofficial documentation, official documentation is not presented in a way that meets the needs of the user;
- by common admission, work is routinely done not according to the requirements of the maintenance manual. This is particularly the case when task requirements are not clear;
- few organisations systematically attempt to monitor how work is actually carried out, being more concerned to ensure that the documenta-

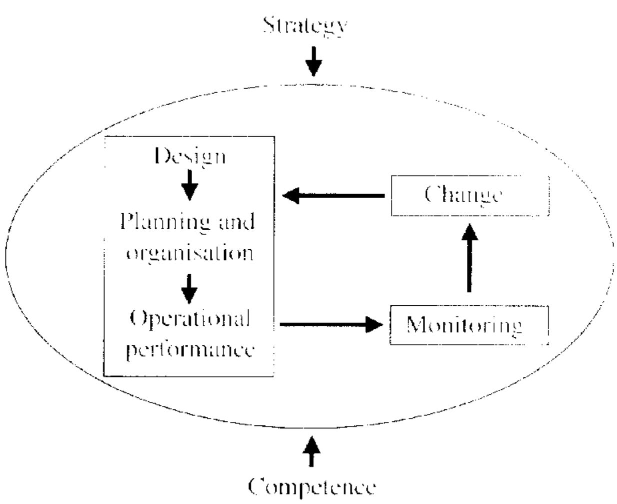

Figure 1. *A systems approach to human centred management.*

tion is signed off in order;
- quality systems do not, in general, provide an effective method of gathering feedback, and, even when they do this, they do not provide a means of ensuring corrective action;
- there is no transparent system (either within organisations or involving official national agencies) for demonstrating effective response to incidents through implementing recommendations designed to prevent similar incidents happening again.

The double standard

Putting this evidence together leads inexorably to the following conclusion:
- there are two parallel systems of work in operation - an official one, and the way in which work is actually being carried out. These two may overlap to some degree; however, there are considerable areas of divergence;
- there are no currently effective mechanisms for reconciling discrepancies between these two systems, whether in terms of immediate feedback and adjustment, auditing how work is performed, quality reporting, or response to incidents.

This can only be described as a 'double standard'. The 'official standard' for task performance has a strong paper trail from the manufacturer to the maintenance organisation and back, through auditing, to the national authority. The 'actual standard' relies on unofficial documentation and informal work practices. We should not infer that this system is inherently unsafe. It certainly lacks the transparency which might give an independent observer confidence in the system. Thus, technicians believe that there often are better and quicker ways of doing task than those they understand to be officially sanctioned by the manual. It is not very difficult to find instances of where this is the case when one examines task performance and documentation in detail. However it is also possible to highlight instances where unofficial methods are pursued in apparently inappropriate circumstances.

Thus, in so far as unofficial methods may be inherently worse than official methods (which come with the authority of the designers) the system may be inherently unsafe. In so far as such methods may be better than the official methods, the system may be much safer through using the experience and judgement of professional technicians. Either way, it is clear that the system does not allow for effective learning so that the system as a whole can be made both more safe and efficient. We should be cautious, however, because even if we believe in the effectiveness of unofficial checks and balances in maintaining system safety, this may be true only for a stable system. When such a system is subject to externally produced changes (new technology, change in organisation or personnel) the implications for safety will be very difficult to predict, and minor, apparently innocuous changes in technology, organisation or personnel may have profound consequences for safety.

A systems approach

One of the main conclusion of the above is that a systematic approach to ensure feedback and learning throughout the maintenance system is essential. We can express the requirements of a Human-Centred Management System as a set of core assumptions as follows:
- design, plan and organise operations to the best possible standard;
- adapt and adjust to deal with unforeseen situations, and learn from experience;
- creating the conditions for optimal task performance is necessary for safety, reliability and efficiency.

Components of this generic approach are illustrated in *figure 1* and the following paragraphs outline how various RTD initiatives, which have been developed in response to this analysis, address the elements of the diagram.

Design for maintainability

The development of design for maintainability guidelines and the integration of these guidelines into design tools and standards is one of the main strands of the work-programme of a new project under the CSG Aeronautics programme - ADAMS-2 - Human centred systems for aircraft dispatch and maintenance safety. This is due to run between 2001and 2004.

Planning and organisation

Many of the key findings and recommendations of the ADAMS project were consolidated into a Guide to Human-Centred Management in Aircraft Maintenance. This includes best practice guidelines for human factors in maintenance and an outline of how these topics relate to the requirements of JAR 145. A case study on flexible planning illustrates some requirements of the effective coordination of maintenance operations.

Operational performance

Developing an in-depth analysis of the task and professional skills of maintenance operations is one of the basic requirements underlying the possibility of developing more effective human-factors interventions. This has been a core task of an IST-funded project with the acronym AITRAM, as well as comprising an important strand of ADAMS-2. In the latter the development of a methodology for the assessment of critical professional skills will enable systematic comparison of different occupational groups. Cognitive task analyses of key maintenance tasks will complement this work. This will lead to a generic understanding of task and professional skills requirements, which will feed into design guidelines, auditing and event analysis methodologies and training specifications.

Monitoring and change

Several parallel initiatives address the requirements for monitoring and change. ADAMS-2 will develop a set of demonstrator quality auditing methodologies at the level of task performance, professional skills and organisational reliability systems. A separate project is developing a continuous improvement system spanning both the maintenance organisation and the aircraft manufacturer (AMPOS - Aircraft maintenance procedure optimisation system - Esprit programme, 1999-2001). This comprises an IT-based methodology for processing and managing cases. An organisational framework for managing the improvement process has been developed in both organisations. Results so far have demonstrated that even simple cases involve complex solutions - organisational mechanism need to be in place to ensure that recommendations are effectively implemented and reviewed.

One of the achievements of ADAMS was to develop an 'Occurrence reporting form' and error taxonomy. This will be further developed in ADAMS-2 as a comprehensive prototype event-management system. This will incorporate a risk-awareness and management system built around incident reporting and risk management prototype databases. The objective here is not just to support the processing of individual events but to facilitate a strategic approach to risk management.

Competence

Training to develop human factors competence is, of course, one of the elements which is critical to successful implementation of the different components of a human-centred management. Building on the initial findings of the ADAMS project, initiatives to develop, implement and evaluate training have been pursued at three levels:

- a core human factors training programme adaptable for training for training technicians, trainers, supervisors and managers has been completed in the STAMINA project (Leonardo programme);
- a cost-effective approach to ensuring effective human factors training requires the integrating human factors into technical training. AITRAM (IST programme) is developing a virtual reality environment to demonstrate how this should be done;
- developing competence in-depth for human factors specialists is critical to ensuring that the opportunities for change are taken, and that human factors programmes are effectively managed. The STAMP project (Leonardo programme) is developing accredited training courses for such specialists.

Strategy for change

If human factors programmes are to be more successful in the future than they have been in the past, then they need to offer a strategic vision not only of what benefits thy can bring to the organisation, but also of how to achieve these benefits. A major strand of the ADAMS-2 project is to develop an organisational model of the implementation process for the tools and methodologies developed in the projects described here. In parallel with this a strategic cost-benefit model will be developed. Both the organisational and cost-benefit models will be tested and elaborated through implementation case studies.

Conclusion

The ADAMS project has documented major deficiencies in how the aircraft maintenance system manages non-technical (human factors) information. These deficiencies can be characterised as a double standard - an official way of working, which is publicly acknowledged, and an unofficial way in which much maintenance work is actually done. Breaking down this double standard will require a comprehensive systems approach. Projects building on ADAMS are developing new tools and methodologies to support a co-ordinated strategy to improve design for maintainability, the planning and organisation of work, monitoring of operational performance, and change in maintenance systems and operations. ■

Acknowledgements

The ADAMS Project (Human Factors in Aircraft Dispatch and Maintenance Safety) was funded under the European Commission Brite-Euram programme. Project number BE95-1732.

The ADAMS 2 Project (Human Centred Systems for Aircraft Dispatch and Maintenance Safety) is funded under the European Commission Competitive and Sustainable Growth programme. Project number GRD1-2000-25751.

The AITRAM Project (Advanced Integration Training in Aeronautics) is funded under the European Commission Information Society Technologies programme. Project number IST-1999-12241.

The AMPOS Project (Aircraft Maintenance Procedure Optimisation System) is funded under the EU Esprit programme. Project no. EP 29053.

The STAMINA Project (Safety Training for Aircraft Maintenance) was funded under the EU Leonardo Programme. Project number IRL/97/1/31013/PI/111.3.a/FPC.

The STAMP Project (Specialised Training for Aircraft Maintenance Professionals) is funded under the EU Leonardo Programme. Project number IRL/001B/F/PP-119.217.

References

(1) McDonald, N., Corrigan, S., Daly, C. & Cromie, S., Safety management systems and safety culture in aircraft maintenance organisations. Safety Science 34 (2000) 151-176.

(2) McDonald, N. (ed.), Human-Centred Management for Aircraft Maintenance. ADAMS project report. Department of Psychology, Trinity College Dublin, 1999.

(3) Air Accident Investigation Branch (AAIB), Report on the incident to BAC 1-11, G BJRT over Didcot, Oxfordshire on 10 June 1990, HMSO, London, 1992.

(4) Air Accident Investigation Branch (AAIB), Report on the incident to Airbus A320-212, G-KMAM at London Gatwick Airport on 26th August 1993, HMSO, London, 1995.

(5) Air Accident Investigation Branch (AAIB), Report on the incident to Boeing 737-400, G-OBMM, near Daventry, on 23 February 1995, HMSO, London, 1996.

(6) Smart, K., Presentation to European Transport Safety Council conference on accident investigation. ETSC, Brussels, 1997.

About the author:

Nick McDonald works in the Aerospace Psychology Research Group in the Department of Psychology of Trinity College, Dublin.

nmcdonald@tcd.ie

http://www.tcd.ie/Psychology/aprg/index.html